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RESEARCH REPORT

U.S. DEPARTMENT OF THE INTERIOR – BUREAU OF LAND MANAGEMENT

IMPROVEMENT OF MOUNTAIN MEADOWS IN NEVADA

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SUMMARY AND RECOMMENDATIONS

This report describes five methods used to improve mountain meadows for livestock, wildlife, and site stability.

Mountain meadows in poor condition were improved rapidly through seeding. A summer fallow gave excellent control of competitive vegetation (sedge, cheatgrass, and povertyweed) before seeding to useful species. Planting in furrows gave the best stand of seedlings and of established perennial grasses. Acceptable stands of seeded grasses were easier to obtain in the sedge type than in the cheatgrass type. Therefore, improvement by seeding should be done before the site has deteriorated to a very poor range condition. Seedling stands of Luna pubescent and Amur intermediate wheatgrasses were similar, but pubescent wheatgrass produced more than did intermediate wheatgrass in some years. Ladak alfalfa and Eski sainfoin stands averaged one plant/3 ft. of row. Herbage of these seeded forbs was of similar quantity and quality as that in good sage grouse habitat.

Mountain meadows in fair condition, but with dense stands of Rocky Mountain iris were improved through use of 2,4-D.[1/] Excellent iris control was obtained with 2 lbs./acre 2,4-D applied from mid-June to early July, when iris was in late vegetative to bloom stage. Generally, a large yield increase by grass and grass-like species was obtained the first year after treatment and in subsequent years. Nevada bluegrass and slender wheatgrass gave the greatest yield increase. Therefore, iris control treatments should be made on sites with good residual stands of these grasses. Yields of the important sage grouse food plants, common dandelion and western yarrow, were severely reduced the year of treatment and the first year after treatment. Total forb production and the dandelion component appeared adequate for sage grouse habitat the second year after treatment.

Small meadows improved by seeding or iris control may justifiably be fenced when required to meet wildlife habitat requirements with livestock use designed to maintain quality wildlife habitat.

1/ All agricultural chemicals recommended for use in the report have been registered by the Environmental Protection Agency. They should be applied in accordance with the directions on the manufacturer's label as registered under the Federal Environmental Pesticide Control Act (FEPCA).

Response of native grass, grass-like, and forb species to nitrogen fertilization on meadows in fair condition depended on climatic conditions, plant vigor, and rates of nitrogen. Little or no forage increase was obtained in a dry year or following a dry year. Slender wheatgrass and Nevada bluegrass gave the largest yield increases. Responses of iris and sedge varied with location. At one location, after 4 years of fertilization, iris was suppressed. This suggests that reduction in iris through competition from vigorous fertilized stands of slender wheatgrass and Nevada bluegrass may be an alternative to chemical control in some situations.

Routine use of nitrogen fertilizer on mountain meadows is not recommended under the present level of management. However, under intensive grazing management, nitrogen could be used to accomplish certain objectives. For example, nitrogen fertilization of low-vigor perennial grasses could increase vigor rapidly during a rest year. Fertilization of vigorous stands of slender wheatgrass or Nevada bluegrass could increase herbage production for livestock use. Fertilization could also be used to maintain forage quality on the seed-ripe or other late-use pasture.

Fertilization of small stringer meadows in sage grouse habitat is not recommended, because nitrogen does not increase dandelion and yarrow production. In addition, stimulation of grass and grass-like species could result in a reduction in forbs because of competition.

Tree and shrub species were successfully introduced into the mountain meadow ecosystem. Best results were obtained by spring planting of container-grown stock within 3 feet of the water line on sparsely vegetated stream banks or dam faces. On areas with dense herbaceous native vegetation, a scalping treatment before planting would be necessary to reduce competition until plants become established. The best species were golden willow, Siberian pea, and common bladdersenna. A method is needed to keep plants dormant until planting. This would reduce premature initiation of growth and reduce the shock of transplanting. Transplants should be protected from livestock grazing for at least 3 years or until well established.

Peak water flow from spring runoff was greatest during the wettest year. Willow Creek ran over its banks only during the wettest year and only at one location on the channel. All drop-inlet pipes in the water control structures except one, in 1 year, had the capacity to handle stream flow. The two dams in the deepest channel did not hold water through the summer of any year. None of the structures at Willow Creek failed. Some of the dams at Long Meadow constructed without a core trench failed. The small amount of sediment deposition behind the dams indicates that channel filling at Willow Creek is a slow process, except in years of catastrophic runoff conditions. An effective dam can raise the water table. After a channel is cut, an effective dam is necessary to raise the water table to a level required by mesic, productive meadow species. The height of water table maintained will influence the productivity of native and introduced species.

IMPROVEMENT OF MOUNTAIN MEADOWS IN NEVADA[2/]

Richard E. Eckert, Jr.[3/]

INTRODUCTION

Mountain meadows occur next to streams and seeps in mountainous topography in northern and central Nevada. Deep, fertile soils and good soil moisture relations from a water table contribute to a productive potential much greater than, and a vegetative composition much different from, that on nearby sagebrush[4/] range. Dominant tall-statured grasses are: Nevada bluegrass, slender wheatgrass, and meadow barley. Low-growing grass and grass-like species include: mat muhly, bluegrass species, sedges, and rushes. Common forbs are: Rocky Mountain iris, western yarrow, common dandelion, and pale agoseris. These meadows are small (several hundred square feet to several hundred acres), yet the productive potential and species composition make them important sources of livestock forage (Cornelius and Talbot, 1955), big game habitat (Patton and Judd, 1970), and the primary summer habitat for sage grouse (*Centrocercus urophasianus*) in Nevada (Savage, 1968; Savage, et al., 1969; and Oakleaf, 1971).

2/ The study was a cooperative effort among the Agricultural Research Service, U. S. Department of Agriculture; the Agricultural Experiment Station, University of Nevada, Reno, Nevada; the Bureau of Land Management, U. S. Department of the Interior; and the Nevada Department of Fish and Game.

The author acknowledges the financial assistance of the Bureau of Land Management and the Nevada Department of Fish and Game and their help in selection and protection of study areas. Field agents of the Nevada Department of Fish and Game also assisted in collection of weather data.

3/ Range Scientist, Agricultural Research Service, U. S. Department of Agriculture, University of Nevada, Reno, Nevada.

4/ A list of common and botanical names of species mentioned appears on page 38.

Mountain meadows in Nevada are in one of the following range condition classes: (1) fair to good condition, with desirable species suppressed by improper livestock use; (2) fair condition, but with desirable species suppressed by dense stands of iris; and (3) very poor condition, with sedge or cheatgrass and povertyweed. This report deals with methods of meadow improvement for livestock, wildlife, and site stability through seeding, iris control, fertilization, tree and shrub transplants, and water control structures. Studies were conducted at two locations (Fig. 1).

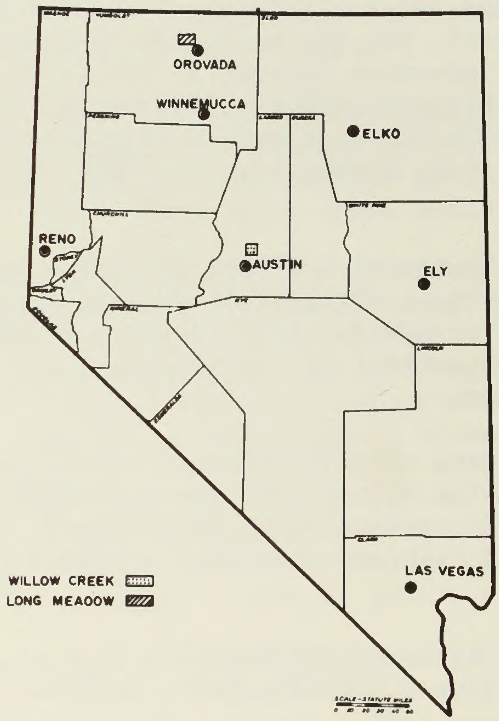

Figure 1. Location of Willow Creek and Long Meadow study sites.

Willow Creek

This site is located 8 miles north of Austin in central Nevada at 7,400 ft. elevation. Some of the climatic characteristics are given in Table 1.[5/] Precipitation from 1964 to 1972 ranged from 8.1 to 33.2 in. and averaged 16.6 in.

The upper site in the Willow Creek meadow complex was a sheep bedground, with residual vegetation of cheatgrass and povertyweed (Fig. 2). The stream channel was about 5 ft. deep. June minimum and August maximum water table depths from 1965 to 1971 were 2.0 and 7.6 ft., respectively. The stream flowed most of the year, and a check dam impounded water and maintained a water table. The soil is a member of a fine, montmorillonitic, frigid family of Aquic Haplaxerolls.

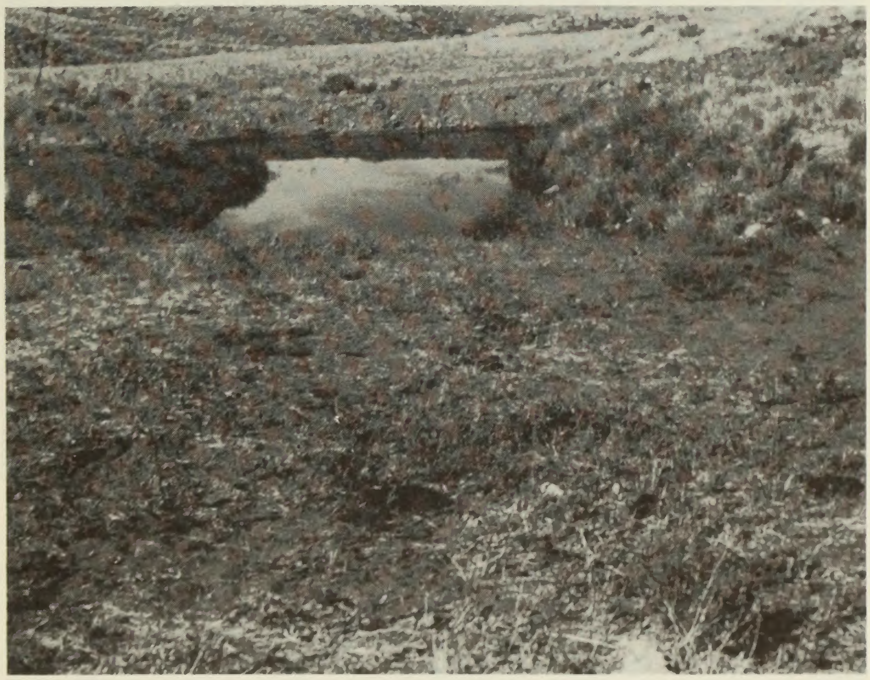

Figure 2. Upper site in the Willow Creek meadow complex. The area was a sheep bedground, with residual vegetation of cheatgrass and povertyweed. A check dam and reservoir on the channel are in the background.

5/ All tabular data are in the appendix.

The middle site was a meadow in fair condition, with slender wheatgrass, Nevada bluegrass, and meadow barley the dominant species (Fig. 3). The stream channel was generally less than 1 ft. deep. June minimum and August maximum water table depths were 1.8 and 13.7 ft., respectively. Water flowed in the stream through July in most years. The soil is a member of a fine-loamy, mixed, frigid family of Cumulic Haplaquolls.

Figure 3. Middle site in the Willow Creek meadow complex. Vegetation is composed of slender wheatgrass and Nevada bluegrass in low vigor, sedge, and iris. The stream channel is about one foot deep.

Vegetation on the lower site was dominated by sedge and suppressed cheatgrass, with a few big sagebrush and rabbitbrush plants (Fig. 4). The channel was 10 to 12 feet deep (Fig. 5) and the check dam did not impound water. The stream did not flow after July in most years. June minimum and August maximum water table depths were 3.5 and 18.8 ft., respectively. Soil is a member of a fine, montmorillonitic, frigid family of Cumulic Haplaxerolls. Studies at Willow Creek

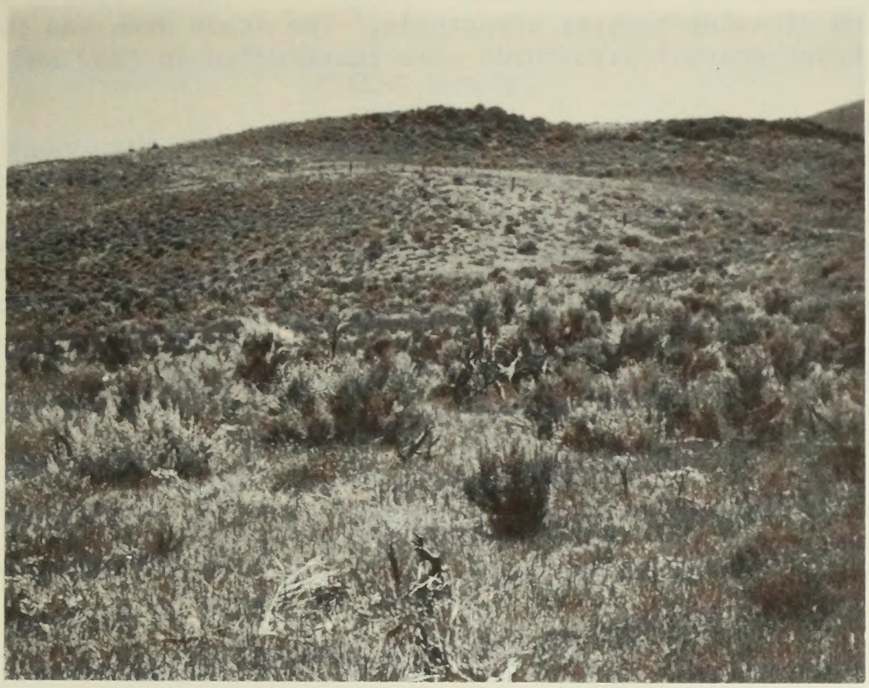

Figure 4. Lower site in the Willow Creek meadow complex. Vegetation is sedge, cheatgrass, big sagebrush, and rabbitbrush. The stream channel is about 12 feet deep.

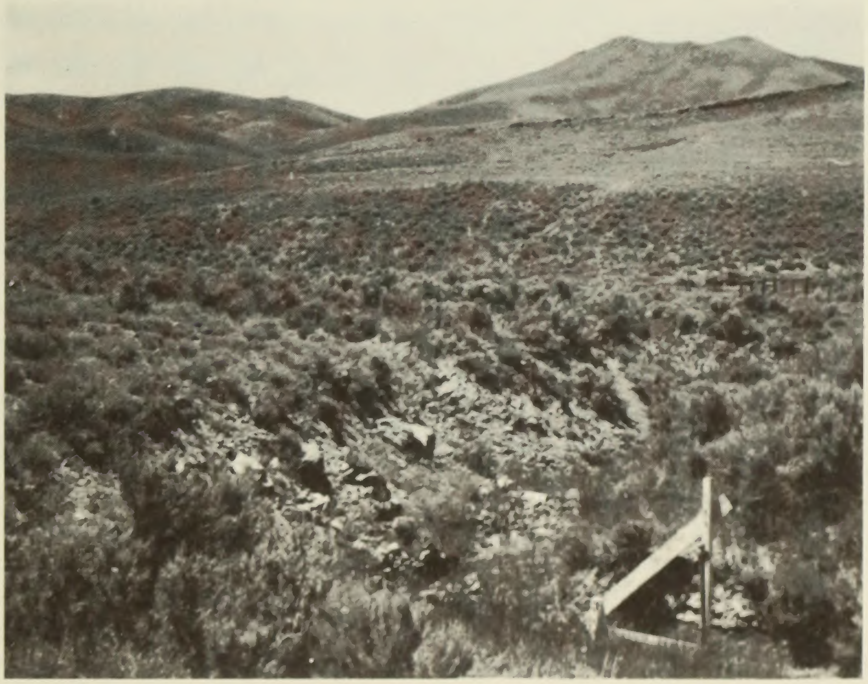

Figure 5. The 12 ft. deep channel in the lower Willow Creek site, with a peak flow gage in the foreground.

included seeding (upper and lower sites), iris control and fertilization (middle site), tree and shrub transplants (upper site), and evaluation of water control structures. The study area was fenced and the water control structures were constructed in 1962 and 1963.

Long Meadow

This site is located in the Lone Willow meadow complex (Fig. 6), about 25 miles northwest of Orovada in north central Nevada, at 6,000 ft. elevation. Precipitation from 1965 to 1969 averaged 20.1 in. and ranged from 15.6 to 25.8 in. (Table 1). The meadow was in fair condition, but the dominant grasses were in low vigor because of improper livestock use and iris competition. The soil is a member of a fine-silty, mixed, frigid family of Typic Haplaquolls. The stream channel was between 2 and 4 feet deep, and water did not run after June. Gully plugs impounded water through August in most years. Studies at this location included iris control, fertilization, and tree and shrub transplants. The study area was fenced and the gully plugs were constructed in 1964. Study methods and results are presented together for each site.

Figure 6. Long Meadow site in the Lone Willow meadow complex. Vegetation is low in vigor because of improper livestock use. Slender wheatgrass, Nevada bluegrass, and iris are the dominant species.

SEEDING STUDIES

Under season-long grazing and livestock concentration, meadows are sacrifice areas (Cornelius and Talbot, 1955). Many are not producing to potential for livestock or wildlife, nor is present cover protecting the site. Channel cutting, lowered water table, and a consequent decrease of desirable native grasses and forbs have reduced productivity. Sedge and iris have increased, and big sagebrush and rabbitbrush have invaded (Cottom and Stewart, 1940; Robertson and Kennedy, 1954; and Yoakum, et al., 1969). Seeding is the best way to improve these very depleted sites rapidly.

Objectives of the seeding studies were: (1) to determine the best method for control of sedge and cheatgrass and seedbed preparation and (2) to evaluate establishment and productivity of seeded grasses and forbs. These studies were conducted only at Willow Creek.

Methods

Studies in 1964 and 1965 at Willow Creek (Eckert, et al., 1973) showed the superiority of the summer fallow treatment for sedge control and of furrowing for survival of seedlings of planted species. Therefore, the summer fallow-furrow technique was used in the 1968 and 1969 studies of species adaptability. A summer fallow was established by plowing in June with a moldboard plow. The seedbed was prepared with a disk-harrow in October. Shovel openers were used to construct furrows about 8 in. deep and 10 in. wide at the top. Seed was drilled immediately after furrowing.

Species seeded in 1968 and 1969 were: Amur intermediate, Luna pubescent and Primar slender wheatgrasses; Regar bromegrass; and Alta tall fescue. Seeding rate was 2 pure, live seeds/in. of row. Eski sainfoin and Ladak alfalfa were seeded alone and in alternate rows with intermediate wheatgrass. These forbs were evaluated as food plants for sage grouse, because dandelion and yarrow were not present on depleted meadows.

Establishment and growth of species were evaluated by plant density (plants/ft. of row - pfr) and yield. Yield samples were taken in 1970, 1971, and 1972 on the 1968 seeding and in 1971 and 1972 on the 1969 seeding.

Water table observation wells were dug to 20 ft., cased with perforated pipe, and backfilled with gravel. Data from these wells were used in the seeding and iris control studies and in the evaluation of water control structures.

Results and Discussion

Seedling establishment

Acceptable stands of pubescent and intermediate wheatgrasses were established on both the cheatgrass-povertyweed type at the upper site (2.0 pfr) and the sedge type at the lower site (3.2 pfr). However, acceptable stands of bromegrass, fescue, and slender wheatgrass were more difficult to establish on the upper site (0.7 pfr) than on the lower (3.1 pfr) site. This is probably because of the greater amount of competitive vegetation on the summer fallow-furrow treatment of the upper site (1,810 lb./acre) than of the lower site (324 lb./acre). Alfalfa and sainfoin stands averaged between one plant per 3.9 and 2.8 ft. of row, respectively, whether seeded alone or in alternate rows.

Forb productivity - 1968 and 1969 seedings

Forb stands were not harvested. However, a yield estimate of 50 to 80 lb./acre of sainfoin was based on the work of Ryerson and Taylor (1968) in Montana under dryland conditions. Alfalfa stands had similar productivity. Oakleaf (1971) calculated that a sage grouse population of 8 birds/acre (the highest density observed in a 4 year study) would consume about 10 lb./acre of forbs during the period of meadow use. A comparison of the forage quality of alfalfa and sainfoin (Jensen et al., 1968) and dandelion and yarrow (Oakleaf, 1971) (Table 2) showed the crude protein, ether extract, and ash in succulent sage grouse food plants were equal to or slightly greater than those in seedbed forbs. Crude fiber was lower in meadow forbs. Quality of seeded forbs was determined on first-cut hay harvested in northeastern Nevada in early July, when sage grouse normally occupy meadows.

Through the seeding techniques and species used, we estalished forbs that appeared to satisfy the quantity and quality food requirements of sage grouse. Sage grouse use of seeded forbs has been established (Patterson, 1952 and Harris, 1972[6/]). Research is needed to determine longevity and reseeding ability of forbs in pure stands, in alternate rows of sodforming and bunch grasses, and under grazing.

6/ Personal communication, Harold L. Harris, Soil Conservation Service, Aberdeen, Idaho.

Grass productivity - 1968 seeding

On the cheatgrass-povertyweed site in 1970, pubescent wheatgrass was the most productive species, followed by intermediate and slender wheatgrasses, bromegrass, and fescue (Table 3). In 1971, production of pubescent and intermediate wheatgrasses was similar and greater than that of the other species. Yield could not be measured in 1972 because of heavy livestock use.

On the sedge site in 1970, the wheatgrasses produced similarly and more than did bromegrass or fescue. In 1971, pubescent wheatgrass produced more, followed by intermediate wheatgrass, bromegrass (Fig. 7), and fescue. Species production ranked the same in 1972. In spite of the dry year in 1972, the introduced wheatgrasses produced more than in previous years, while bromegrass production was similar to that in preceding years. The fescue stand failed in 1972, and this species does not appear adapted to mountain meadow conditions.

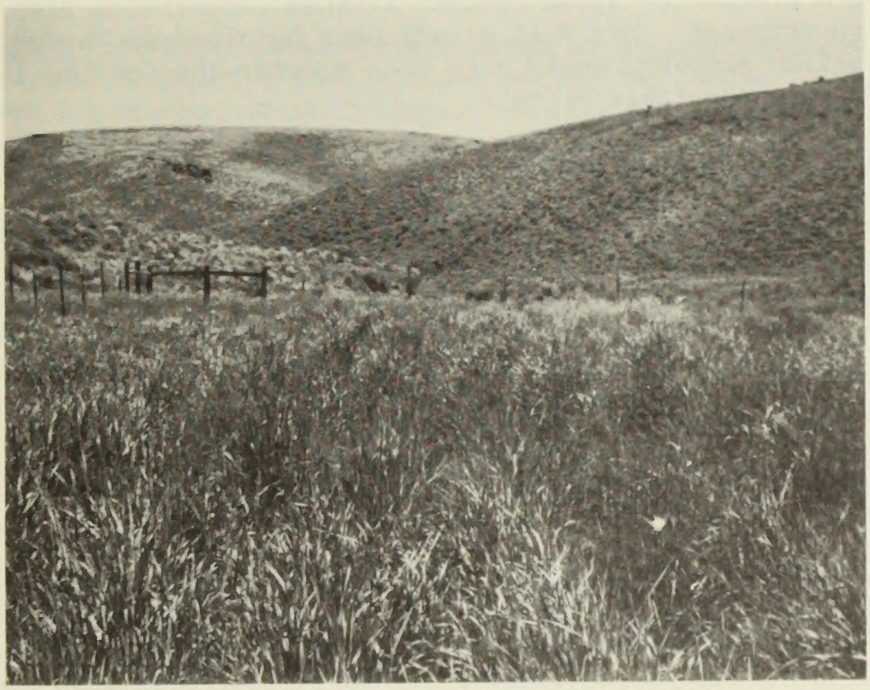

Figure 7. Four-year-old stand of grasses seeded on the lower Willow Creek meadow. Species are Amur intermediate wheatgrass (left of photo), Luna pubescent wheatgrass (center), and Regar bromegrass (right of photo).

Pubescent and intermediate wheatgrasses produced more on the upper site than on the lower site in both 1970 and 1971. Stands were mostly full, and most environmental factors were similar on both sites, but depth of water table varied considerably. Minimum depths were similar. However, by July the water table averaged 5 ft. on the upper site and 8 ft. on the lower site. By August of both years, the water table at the upper site still was 5 ft. At the lower site, the water table was 15 ft. in 1970, 12 ft. in 1971, and 17.4 ft. in 1972. On the upper site, capillary rise above a 5 ft. water table could have increased the amount of soil moisture available to plants, and this additional moisture would explain the higher productivity. On the deeply gullied lower site, the water table and capillary fringe were below root depth after June in most years, and the productive potential was that of a dryland environment.

Bromegrass and fescue produced more on the lower site than on the upper site (Table 3). This response was directly related to the difficulty of obtaining a full seedling stand of these species and maintaining a productive stand against intense competition from cheatgrass and povertyweed. Had full stands been obtained on the upper site, production probably would have been greater than on the lower site, because of the water table effect.

Grass productivity - 1969 seeding

Herbage yields were also determined for species seeded in 1969 on the lower site. In 1971, intermediate wheatgrass in solid stands 2,150 lb./acre) and pubescent wheatgrass (2,300 lb./acre) produced similarly. Bromegrass (1,421 lb./acre) and intermediate wheatgrass in alternate rows with sainfoin or alfalfa (1,454 lb./acre) produced less, and fescue (614 lb./acre) least. In 1972, pubescent (3,307 lb./acre) and intermediate wheatgrass (3,019 lb./acre) in solid stands were the most productive. Intermediate wheatgrass in alternate rows with forbs (1,915 lb./acre) and bromegrass (1,651 lb./acre) produced less, and fescue stands failed again.

Plots of native slender wheatgrass and sedge were not included in the experimental design at the lower site, because stands were too scattered. However, production data are included in Table 3 for comparison. In 1970, yield of native slender wheatgrass was less than for the seeded wheatgrass, but surpassed that of bromegrass and fescue. Sedge production equalled or surpassed that of bromegrass or fescue in both years. In the wet year of 1971, production of slender wheatgrass (3,230 lb./acre) was similar to that of pubescent wheatgrass, and about 1,000 lb./acre more than that of intermediate wheatgrass. Production by the two native species in the dry year of 1972 was less than in 1971 and similar to that in 1970. In 1972 these native species produced about one-half as much as did the introduced wheatgrasses and about equalled production of bromegrass.

Summary and Management Implications

A summer fallow-furrow technique was a very satisfactory method to control competitive vegetation and to seed perennial grasses. Acceptable stands were easier to obtain in the sedge type than in the cheatgrass-povertyweed type, because of less competition. Therefore, site improvement by seeding should be done before this poor range condition is reached. Seedling stands of Luna pubescent and Amur intermediate wheatgrass were similar to each other and superior to those of Regar bromegrass, Alta tall fescue, and Primar slender wheatgrass. Yield of pubescent wheatgrass was equal to or superior to that of intermediate wheatgrass. Bromegrass and fescue were not as productive as the introduced wheatgrass. Native slender wheatgrass was as productive as the introduced wheatgrasses in a wet year, but not in a dry year. Alfalfa and sainfoin stands averaged about one plant/3 ft. of row. Herbage of these forbs was of quantity and quality similar to that in good sage grouse habitat.

Conversion of depleted mountain meadows to productive stands of seeded species will require 1 year non-use during the fallow period and 1 or 2 years non-use for establishment. Fencing for protection during establishment and for future management may be the only practical means of livestock control, because animals will congregate in meadows regardless of the grazing systems used.

Large improved meadows should be managed for livestock and wildlife separately from surrounding dryland range. Fencing and management of small improved meadows would be impractical for livestock production, because of excessive stock moving and the small amount of forage available.

These small areas of improved meadows may justifiably be fenced and managed exclusively for wildlife, particularly sage grouse. Access of livestock to water should be provided by water gaps or piping. Complete protection from livestock is undesirable since seeded grasses may stagnate or may become aggressive and crowd out wildlife food plants. In addition, Oakleaf (1971) found that meadows with dense vegetation were not used by sage grouse. Controlled livestock grazing to open up the grass stand immediately before sage grouse occupancy would be beneficial. However, forb palatability to livestock may dictate development of areas within improved meadows seeded only to forbs and fenced from livestock. Seeded grasses would protect the site, livestock could use the grass to open the stand before sage grouse occupancy, and the unused forbs would be available for wildlife.

IRIS CONTROL STUDIES

Iris is a common plant of native meadows and pastures in Nevada and adjacent States (Cords, 1960). Competition by perennial grasses and other desirable plants on pastures in good condition and mowing on hay meadows restrict iris increase. However, the plant is a serious problem on poorly managed pastures and mountain meadows, because it is unpalatable to livestock (Pryor and Talbert, 1958). Iris reproduces from seed and underground rootstocks. These rootstocks enable the plant to withstand heavy trampling and to spread rapidly when competitive vegetation is weakened (Dayton, 1960). Iris is well adapted to soils with the potential to support species of much greater forage value. Iris reduces the yield of livestock forage and wildlife food plants through competition and also limits grazing because livestock avoid forage in and around iris clumps. In addition, iris has no value as a wildlife food plant (Gullion, 1964). Although iris may furnish some cover for wildlife and may be pleasing from the aesthetic viewpoint, the disadvantages of dense monotypic stands of this species far outweigh the advantages.

Pryor and Talbert (1958), Cords (1960, 1972), and Robocker (1966) indicate the superiority of 2,4-D for iris control. Cords (1960) obtained more than 90% control with 4 lb./acre of ester formulations of 2,4-D, applied soon after bloom. However, none of these authors evaluated the effects of this treatment on nontarget species.

Savage (1968), Savage, et al. (1969), and Oakleaf (1971) showed the importance of meadows for sage grouse habitat and particularly the importance of meadow forbs as food plants during the summer.

Objectives of this study were: (1) to evaluate rates of 2,4-D (2,4-dichlorophenoxy), acetic acid and dates of application for iris control; (2) to determine the response of livestock forage plants after iris control; and (3) to determine the effect of 2,4-D on the sage grouse food plants, common dandelion and western yarrow. Iris control studies were conducted at both Long Meadow and Willow Creek.

Long Meadow

Methods

Propylene glycol butyl ether ester of 2,4-D at 4 lbs./acre was applied in 10 gpa water with 0.1% X-77 surfactant in mid-July, 1965. Another study was initiated in 1968 to evaluate rates of 2,4-D and date of application. Plots were treated in 1968 and 1969 with 2, 3, and 4 lbs./acre of 2,4-D in mid-June and early July. Yields of iris, forage species, and forbs were determined on sprayed and check plots.

Results and Discussion

Iris control

Excellent iris control (91-100%) was obtained with 2, 3, and 4 lbs./acre of 2,4-D applied in mid-June or early July (Figs. 8 and 9). Iris phenology at time of application ranged from late vegetative to late bloom. Reduction in iris yield the first year after treatment averaged 780 lbs./acre.

Figure 8. Iris stand at Long Meadow before treatment with 2 lbs./acre 2,4-D in June 1969.

Figure 9. Stand of Nevada bluegrass at Long Meadow in 1970, one year after 2,4-D treatment. Grass production was 2,167 lbs./acre, compared to 1,023 lbs./acre without treatment. Note lack of forbs in the first year after treatment.

Production of grass and grass-like species

Yields of grass and grass-like species were greater each year after iris was controlled in 1965 (Table 4). Yield increases over that of the check plot ranged from 274 lbs./acre in 1966 to 1,352 lbs./acre in 1970, and averaged 837 lbs./acre or 143%. Productivity was greatest in 1970, less in 1967 and 1969, and least in 1966 and 1968. Low yields in 1966 and 1968 were attributed to adverse precipitation and temperature conditions. With near-normal weather conditions, a greater yield would be expected the year after treatment than that obtained in 1966. Results in 1969 and 1970 support this speculation. Average yield increases the first year after treatment in three studies were 1,442 lbs./acre (340%), 2,364 lbs./acre (360%), and 1,135 lbs./acre (111%).

Iris control on sites dominated by Nevada bluegrass resulted in a yield response by this species the first year after treatment, (558 lbs./acre) compared to the check (160 lbs./acre). During the next 4 years, yields varied between 160 and 502 lbs./acre on the check and between 520 and 1,100 lbs./acre on 2,4-D treated plots. Slender wheatgrass responded slowly on these sites, with an average yield the first 3 years of 16 lbs./acre. In the fourth year, yield was 280 lbs./acre, and in the fifth year 800 lbs./acre (Table 5).

Iris control on sites dominated by slender wheatgrass resulted in a yield response by this species the first year after treatment. Pretreatment yield in two studies averaged 88 lbs./acre. After 1 and 2 years, respectively, yields were 1,450 and 1,300 lbs./acre. Yield of Nevada bluegrass was 372 lbs./acre before treatment and 650 and 600 lbs./acre 1 and 2 years after treatment.

Forb production

Oakleaf (1971) calculated that the sage grouse population of 8 birds/acre at Long Meadow would consume about 10 lbs./acre of forbs during meadow occupancy. On this basis, total forb production the year after treatment (Table 6) was deficient or minimal for the sage grouse population, except on plots treated with 2 or 3 lbs./acre of 2,4-D in early July. Total forb production the second year after treatment appeared adequate, except on plots treated with 4 lbs./acre of 2,4-D in early July (Fig. 10). Yields of sage grouse food plants 3, 4, and 5 years after treatment were 96, 200, and 160 lbs./acre, respectively, with 20, 24, and 32 lbs./acre of dandelion. Two factors, other than total forb yield, need consideration. Dandelion is the preferred species (82% of meadow forbs consumed), compared to yarrow (7%) (Savage, 1968). A forb component of least-preferred species will not satisfy sage grouse needs. The year after treatment, dandelion production (Table 6) was low on most treatments. Therefore, even though total forb production approached 10 lbs./acre, this production would not be considered adequate for good sage grouse habitat. Dandelion production the second year after treatment did appear adequate for good sage grouse habitat. Data on total forb and species yield can be misleading, because sage grouse do not consume the entire plant, but remove the more succulent portions. We do not know the total production necessary to supply the required intake of succulent parts.

Figure 10. Untreated stand of iris in foreground at Willow Creek, and area treated with 2,4-D two years previously in background. Note lack of forbs in dense monotypic iris stand, and good stand of forbs on treated area after two years.

Willow Creek

Methods

Methods used in the 1968 and 1969 studies at this location were identical to those used at Long Meadow.

Results and Discussion

Iris control

Excellent iris control (94 to 100%) was obtained with 3 or 4 lbs./acre of 2,4-D applied in mid-June or early July. Iris phenology at time of treatment ranged from late vegetative to late bloom. The 2 lbs./acre treatment of 2,4-D in early July gave from 73 to 85% control. This treatment appears near the minimum rate of 2,4-D needed for excellent iris control, when applied after seed capsules start to form. Reduction in iris yield on successful treatments averaged 1,200 lbs./acre.

Production of grass, grass-like, and forb species

Yield increases of grass and grass-like species the first year after treatment averaged 690 lbs./acre (99%). Although the total vegetative response to 2,4-D treatment was similar to that at Long Meadow, productivity was one-half to two-thirds as much. Differences in productivity between the two sites was caused by a greater density of the more productive species, such as slender wheatgrass and Nevada bluegrass, at Long Meadow. Yields of dandelion and yarrow in the first 2 years after treatment were similar to those at Long Meadow.

A large yield response by grass and grass-like species was found in 10 of 11 measurements of 2,4-D treatment effects. The exception in 1969 at Willow Creek, was attributed to a persistent water table at 4.5 ft. In comparison, water table depths from 1965 to 1971 ranged from 8 to 13 feet. Very high precipitation (33.2 in.) in 1968-69 contributed to the high water table by water percolating through the soil and by underground flow from the surrounding watershed. A shallow water table would produce a capillary fringe within the root zone of perennials. No yield response to 2,4-D application under conditions of high precipitation and high water table suggests that the main effect of iris control is to conserve soil moisture. A comparison of 1969 and 1970 yields revealed that apparent lack of response in 1969 was caused by increased check yield, not by reduced treatment yield.

Summary and Management Implications

Mountain meadows with dense stands of iris can be improved for livestock and wildlife. Excellent iris control was obtained with 2,4-D at 2 lbs./acre applied from mid-June to early July, when iris was in late vegetative to bloom stage. Treatment after seed capsules start to form will require more herbicide for similar control, or acceptance of less uniform or reduced control.

If environmental conditions are near normal, a large yield response by grass and grass-like species can be expected the first year after treatment and in succeeding years. Total yield and species response depend on meadow condition and species composition at time of treatment. Therefore, meadows with a residual stand of slender wheatgrass and Nevada bluegrass should be treated first.

Yield of important sage grouse food plants, dandelion and yarrow, was severely reduced the year of treatment and the first year after treatment. Production of the preferred species, dandelion, was not adequate for the existing sage grouse populations. Total forb production and the dandelion component appeared adequate for sage grouse habitat the second year after treatment.

Variability in range conditions, species composition, and water table results in degrees of iris infestation. In dense stands of iris, forbs are almost eliminated, and suppressed perennial grasses are found in iris clumps. Treatment of these dense stands would increase grass production and open the community for forb reproduction. On most meadows, spot treatment can be done with a backpack sprayer. With such equipment, the applicator has more control over spraying nontarget areas such as good forb stands and streams. Untreated areas will supply forbs for sage grouse while forb production is reduced after treatment. In an intensive improvement program, different portions of the meadow can be treated periodically until iris is no longer a problem.

Vegetation management after iris control is important. Perennial grass in iris clumps is in low vigor. Therefore, the large response in vigor and seed production by grass does not occur until a year after treatment. Livestock use should be deferred until after seeds are ripe, to disperse and trample grass and forb seeds. This should be followed by deferment long enough for seedling establishment before normal use. Small treated meadows may best be managed primarily for wildlife, with livestock use designed to maintain quality wildlife habitat.

FERTILIZATION STUDIES

Meadow fertilization research has shown that nitrogen application can increase yield, crude protein, palatability, root growth, and vigor of plants (Wilhite et al., 1955; Leamer, 1963). In these studies, fertilizers were spring-applied and moved into the soil with irrigation.

Mountain meadows in Nevada generally are not irrigated, therefore, fertilizers must be fall-applied and moved into the soil by winter precipitation. The literature contains only two studies that approximate conditions found on nonirrigated meadows in Nevada. Cook (1965) applied nitrogen to 16 mountain meadows in northern Utah. Nitrogen at 60 lbs./acre increased grass and forb yield, protein content, and palatability. Browns (1972) reported that nitrogen and phosphorus application increased production, crude protein, and phosphorus content of herbage on high-elevation native meadows in southwestern Utah. The residual effect of one application of 60 lbs./acre nitrogen plus 60 lbs./acre phosphorus carried over two growing seasons for increased production, three seasons for increased phosphorus in plants, and one season for crude protein and gross energy of herbage. Neither Cook nor Browns reported yields for individual grass, grass-like, or forb species.

Objectives of the fertilizer study were: (1) to determine the effect of added nitrogen on total productivity, (2) to determine the effect of repeated applications of nitrogen on species composition, and (3) to evaluate the response of forbs to nitrogen fertilizer. Fertilization studies were conducted at both Long Meadow and Willow Creek.

Long Meadow

Methods

The study was conducted for 3 years on a site judged to be in fair range condition; however, perennial grasses were in low vigor from improper livestock use. Nitrogen, as ammonium nitrate, was fall-applied yearly to the same plots at rates of 0, 50, 100, and 200 lbs./acre. Species yields were determined each year.

Results and Discussion

The 1965 yield data represent productivity the first year after fencing (Table 7). Fertilization did not increase total production nor production of desirable species. Apparently the desirable species such as Nevada bluegrass and slender wheatgrass were in such low vigor that they could not make use of the additional nitrogen. Less desirable species, such as yarrow and iris, dominated the site and competed with the grasses for soil moisture and nutrients other than nitrogen. Dandelion was not found on any plot.

Perennial grass production in 1966 was much less than in 1965, and none of the grasses responded to nitrogen fertilization. Total precipitation was 5 in. below average, and spring moisture was much below average. Sedge production in 1966 was much greater than in 1965 and responded to the 100 and 200 lbs./acre rates of nitrogen. Yarrow produced less than in 1965, probably because of the lower precipitation, and did not respond to nitrogen fertilization. Dandelion was not found on any plot. Possible explanations for the absence of dandelion include: (1) a very small seed source; (2) a spring precipitation pattern unfavorable for germination of this species; or (3) the dense growth of sedge formed a closed community too competitive for establishment of dandelion seedlings.

Weather conditions in 1967 were about average for the study period. Nevada bluegrass was the only perennial grass that responded to nitrogen fertilization. With 100 and 200 lbs./acre of added nitrogen, this species produced 291 and 225 lbs./acre more than did the check. Yarrow production was greater than in either 1965 or 1966, but this species did not respond to nitrogen. A possible combination of a favorable weather and lack of sedge competition resulted in a dense stand of dandelion; however, this species did not respond to nitrogen.

Willow Creek

Methods

Fertilization studies were conducted for 4 years on a site judged to be in fair condition, but with perennial grasses in low vigor because of improper livestock use. Nitrogen treatments and sampling methods were identical to those used at Long Meadow.

Results and Discussion

Results at Willow Creek were different from those at Long Meadow (Table 8). Nevada bluegrass did not respond to nitrogen fertilization the first year, but did respond to 200 lbs./acre of added nitrogen in 1965 and 1966 and to all rates of nitrogen in 1967. Slender wheatgrass made a large yield response to all rates of nitrogen in 1964 and 1967, and a small response in 1965 and 1966. Sedge responded to all rates of nitrogen in 1964, 1966, and 1967, but no response was obtained in 1965. Iris production was increased by all rates of nitrogen in 1964, but no subsequent response was obtained. In fact, nitrogen at 100 and 200 lbs./acre suppressed iris in 1967. This reduction may have been caused by the large grass production in these two treatments. Yarrow did not respond to treatments in 1964, 1966, or 1967. This species did respond in the dry year of 1965, perhaps because production of grasses and sedge was low, and more nitrogen was available to this forb species. Dandelion did not respond to nitrogen in any year.

Summary and Management Implications

Responses of native grass, grass-like, and forb species to nitrogen fertilization depended on climatic conditions (mainly precipitation), plant vigor, and rate of nitrogen.

Little or no response was obtained in a dry year, and the response following a dry year was generally poor also.

Stands of slender wheatgrass in low vigor responded to all rates of nitrogen in a normal year. Response of low-vigor Nevada bluegrass stands was minimal. Application of nitrogen to vigorous plants of either species increased yield, but the response by slender wheatgrass was greater than that for Nevada bluegrass when both species were growing together. In addition, slender wheatgrass responded to the lowest rate of nitrogen, while Nevada bluegrass responded only to the two highest rates.

Sedge production was increased by the lowest rate of nitrogen at Willow Creek, but no response was obtained at Long Meadow. At Long Meadow, the response of sedge appeared to depend more on environmental conditions and plant competition than on nitrogen. Highest sedge yield was obtained in a dry year, when production by perennial grasses was very low.

Iris did not respond to nitrogen at Long Meadow. At Willow Creek, iris yield was increased by all rates of nitrogen only the first year after treatment. After the fourth year of treatment, iris was suppressed on plots treated with the two highest rates of nitrogen. This suggests that competition from slender wheatgrass and Nevada bluegrass in 1967 effectively reduced the iris stand. Reduction of iris through competition may be an alternative to chemical control in some situations.

Dandelion and yarrow did not respond to nitrogen treatments at either location in any year. Response by these forbs appeared to depend more on environmental conditions and competition.

Routine use of nitrogen fertilizer on mountain meadows is not recommended under the present level of management. However, fertilization could be used to accomplish certain objectives in a management system. For example, nitrogen fertilization of low-vigor perennial grasses might increase vigor rapidly during a rest year. Fertilization of vigorous stands of either slender wheatgrass or Nevada bluegrass could increase herbage production for the livestock use year. Fertilization could also be used to maintain forage quality on the seed-ripe or other late-use pastures, on which quality is generally poor. These objectives could be attained without fencing. However, fencing of the large treated meadows would be desirable, because an increase in forage palatability could increase the problem of livestock concentration and over-use.

Fertilization of small stringer meadows in sage grouse habitat is not recommended, because nitrogen does not increase dandelion and yarrow production. In addition, stimulation of grass and grass-like species could result in a reduction in forbs because of competition.

Additional work is needed to determine the best type of nitrogen fertilizer. In the study, only ammonium nitrate was used. Some of the soluble nitrate may have been leached below the root zone by heavy winter precipitation before plant growth began in the spring. Urea is not subject to leaching, but must be converted to the nitrate form before uptake by plants. Cold spring weather and cold and water-logged soils may hinder this conversion, so that nitrogen is unavailable to plants early in the spring. A slow-release fertilizer could be used if the amount of nitrogen released in the spring was sufficient for plant needs. Other possible problems associated with use of nitrogen fertilizer include nitrogen pollution of the stream and groundwater, and grass tetany under certain environmental conditions.

TREE AND SHRUB TRANSPLANTS

Some stream banks and meadows in Nevada support riparian tree and shrub species. These plants create such a distinctive appearance that some ecosystems are named after them. Evidence indicates that certain stream bank trees and shrubs were more prevalent in the past than now. Reestablishment of trees and shrubs is one method of revegetation to stabilize stream channels and check dams, to create wildlife habitat, and to increase aesthetic values (Yoakum and Dasmann, 1969).

Most of these studies were conducted at Willow Creek.

Methods

Tree and shrub transplants were made in June 1966, 1967, and 1968 at Willow Creek and in June 1967 at Long Meadow. Species used were: American plum, black chokecherry, cardinal olive, common bladdersenna, common lilac, European sagebrush, golden willow, Russian olive, Siberian pea, and Tatarian honeysuckle.

Material for the 1966 planting was obtained as bare-root nursery stock dug in March and April and "heeled in" at a cool, shady location. This bare-root stock was planted at Willow Creek in June, when the area was accessible. Plummer, et al. (1968)

strongly recommend spring planting, unless supplemental water is available. The 1967 and 1968 plantings were made with container-grown materials. Bare-root nursery stock (1 to 2 years old) was obtained each year in March and April and planted in 1-gallon waxed paper containers. Paper was removed at planting time. Both bare-root and container-grown plants were placed in holes twice the size of the roots, the holes were filled, small basins were constructed around the plants, and water was added to settle the soil around the bare roots or balls of soil.

Plantings were made on four sites: (1) on sparsely vegetated stream banks at points 1, 3, and 6 ft. above the water line; (2) in the same positions on a well-vegetated bank; (3) in the same positions on the inside faces of check dams; and (4) next to reservoirs behind check dams. All species were not planted on all sites in all years, because of lack of plants and space. Results were based on a 3-year evaluation of each planting.

Results and Discussion

The time lag between removal of plants from the nursery and transplanting on the meadow was up to 3 months. This delay was caused by inaccessibility of the meadow, snowdrifts, and frozen soil at the planting site. Holding plants for this length of time would probably best be done in containers rather than bare-root. Although the bare-root technique is cheaper, plants may suffer more of a shock when transplanted. With either type of material, leaf, root, and shoot growth began before planting. Stock in this condition is more subject to shock from transplanting, desiccation, and freezing than dormant stock. A solution to this problem may be to grow materials in an environment similar to the planting site or to keep plants in cold storage until the site is accessible.

About 75% of the transplants made on barren stream banks or on check dams seeded to crested wheatgrass survived through the evaluation period. None of the plantings made in a dense cover of native grasses and sedges survived through the second year. Plant roots were placed in a zone of heavy root concentration of native species and were subject to severe competition for moisture, nutrients, and light from these species. In addition, rodent activity in dense vegetation under snow may also account for death of transplants (Frischknecht and Baker, 1972).

On barren stream banks and check dams, 55% of the trees and shrubs transplanted 6 feet above the waterline survived the first year, none survived the second year. The species used were not adapted to the dryland environment on this site, where the water table was about 6 feet deep.

Survival of transplants made on the stream bank 1 to 3 feet above the waterline was 90%. However, plants nearer the water were more vigorous. For example, in the first and second years after planting, new growth on plants nearer the water was from all parts of the original plant. New growth on plants further from the waterline was from buds within 4 in. of the soil. Plants were dead above this point. In succeeding years, plants on both sites grew normally.

None of the transplants made next to the reservoirs persisted. The constant, very shallow water table or flooding during spring runoff may have prevented establishment.

Golden willow and Siberian pea were the most successful species on both the stream banks and dam faces (Fig. 11). After 6 years, height of golden willow on the stream banks and check dams averaged 4 and 10 feet, respectively, while height of Siberian pea was 3 feet on both sites. Plants of both species were well branched. Bladdersenna has persisted for 6 years, but has not developed as much as golden willow or Siberian pea. Lilac, black chokecherry, European sagebrush, and Russian olive persisted for 1 to 2 years, then died. American plum, cardinal olive, and honeysuckle died the year of planting. None of these species appear to be adapted to the meadow environment.

Figure 11. Golden willow and Siberian pea growing on a check dam at Willow Creek.

The 1966 and 1967 plantings at Willow Creek were protected from livestock use until 1972. In 1972, cattle heavily grazed nearby plots of seeded grasses but only lightly browsed the Siberian pea and bladdersenna. No use was observed on golden willow. Transplants made in 1967 at Long Meadow were destroyed by cattle use soon after planting. Plants were heavily browsed and pulled from the soil, although abundant native meadow forage was available to the animals.

Summary

Tree and shrub species were successfully introduced into the mountain meadow ecosystem. Best results were obtained by spring planting of container-grown stock within 3 feet of the waterline on sparsely vegetated stream banks or dam faces. The best species were golden willow, Siberian pea, and bladdersenna. Bare-root materials can be used, but mortality is greater. On areas with dense herbaceous native vegetation, a scalping treatment before planting would be necessary to reduce competition until plants become established.

A method is needed to keep materials dormant until planting. This would reduce premature initiation of growth and reduce the shock of planting.

Transplants should be protected from livestock grazing for at least 3 years or until well established. Then grazing should be regulated to prevent damage to established plants. Protection from rodents may also be needed in areas of high animal populations.

HYDROLOGIC EVALUATIONS

Mountain meadows generally develop on alluvial fill along water courses, where the slope gradient and stream velocity have decreased and the bedload has been deposited at some past time. Cottom and Stewart (1940) describe the aggradation and degradation processes in meadow evolution. These authors suggest that debris may have blocked stream channels and formed catchment and settling basins. These basins filled with sediments at a rate that depended on surface erosion and size of the watershed. As the basin filled, vegetation developed from the edges toward the center of the pond, and more sediment was trapped, until the basin was filled and completely vegetated with a mesic plant community (Robertson and Kennedy, 1954). At Willow Creek, for

example, the alluvial fill is at least 20 feet deep. These deep sediments are themselves subject to erosion. Climatic changes, damages to upstream watershed, or geologic changes such as tilting, all increase stream flow, sediment load, and erosion potential. Antevs (1952) concluded that most channel cuts resulted from occasional flash floods after vegetation had been severely reduced. In resource management, we want to maintain meadow integrity for livestock forage, wildlife habitat, watershed stability, and aesthetics.

Methods

Water control structures may be one method to halt channel cutting, prevent further site deterioration, and improve meadow condition. Four earth structures with corrugated pipe drop-inlets and one diversion dam were built at Willow Creek in 1962-63 (Figs. 12 and 13). These structures were seeded to crested wheatgrass. Twelve gully plugs with water spreaders were constructed in Long Meadow in 1964. The objectives of both types of structures were: (1) to reduce the channel gradient and erosive power of the stream; (2) to collect sediment to fill the channel, and (3) to raise the water table in the adjacent meadow.

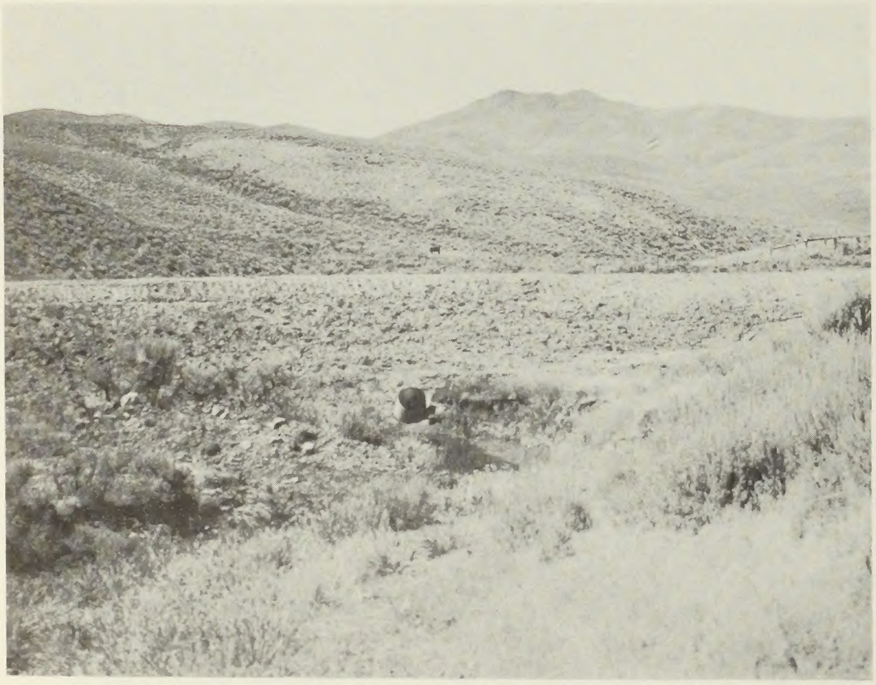

Figure 12. Check dam with corrugated drop-inlet pipes under construction at Willow Creek.

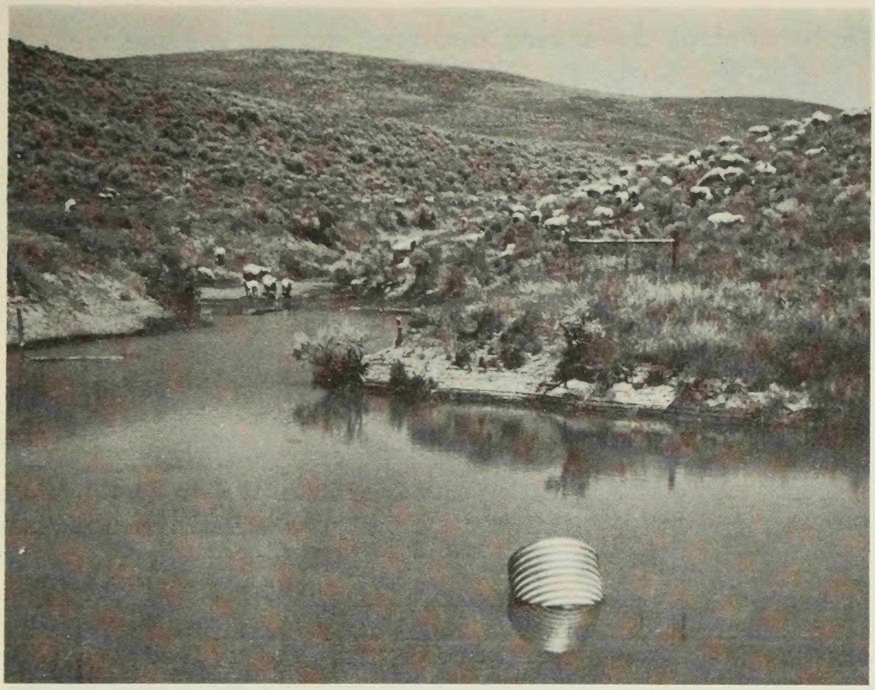

Figure 13. Drop-inlet pipe with extension impounds water behind the check dam to create a reservoir and raise the water table in adjacent meadow.

Maximum height of water in the channel from spring runoff was measured with peak flow gages from 1964 to 1971 at four sites on Willow Creek (Table 9). Peak flow from high intensity summer storms was determined with a water stage recorder mounted on a Parschall[7] flume installed in a channel that is normally dry after June. Structures were visually evaluated for water collection and storage. Sediment deposits behind the structures were measured yearly on reference posts installed at three points behind each dam. Detailed hydrological data were collected only at Willow Creek.

Results and Discussion

Peak water flow from spring runoff varied from 1.5 to 26.0 inches deep during the 7 years of measurement (Table 9). The greatest

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flow at three of four locations occurred during the wet year of 1968-69. Although precipitation during the other years varied between 8.1 and 23.4 inches, peak spring runoff and precipitation were not related. Water depth was greater than the channel depth by 17.5 inches only at one location in 1 year. The stream bank was well vegetated, and no channel damage or debris collection was noted. Also during the 7 years of study, no water flow from high intensity summer or fall storms occurred.

All structures at Willow Creek were designed to impound about one acre foot of water. All drop-inlet pipes, except one, had the capacity to handle the peak water discharge. In 1965 and 1973 water ran over the spillway of one dam and cut a channel through an adjacent meadow. The pipe had a capacity of 47 cfs; therefore, either the flow exceeded this capacity or the pipe plugged. Two structures did not hold water through July or August. These dams were in the lower exclosure in a 10- to 12-ft. deep channel. From 1,000 to 1,300 cu. yds. of fill were required for construction of each dam--about twice the fill used for the other dams. Water may have percolated through the greater area of fill, or perhaps water flowed around or under the dam through permeable strata exposed by the deep channel. One dam held water through the summer in all years. The two structures in the upper exclosure did not hold water in 1963 or 1964, the first 2 years after construction, or in 1966, but did contain some water through the summer and fall of the other 7 years.

The amount of sediment deposited in the reservoir behind the dams varied from a net loss of 1.2 inches to a net gain of 26.2 inches (Fig. 14). The greatest deposits, 26.2 and 16.2 inches, were measured at a sample point closest to the dam in 1964, one year after construction. One of these samples was immediately behind a diversion dam; the other was behind a dam with a large quantity of fill. The sediment can probably be attributed to movement of loose materials from the dam into the reservoir. These sediments remained stable after they were deposited. Excluding these two extremes, 33 sample points showed a net increase in sediment depth of 1.4 inches, and 11 points showed a net decrease of 1.3 inches. Some points showed an increase in deposits in one year and a decrease the next. These changes of from 1 to 2 inches are undoubtedly caused by water currents in the reservoir. The small average amount of yearly sedimentation (1.4 inches) indicates that channel filling is a very slow process at Willow Creek. The exception would be in years of catastrophic runoff, such as in 1973, when 4 feet of sediment filled one reservoir (Figs. 15 and 16).

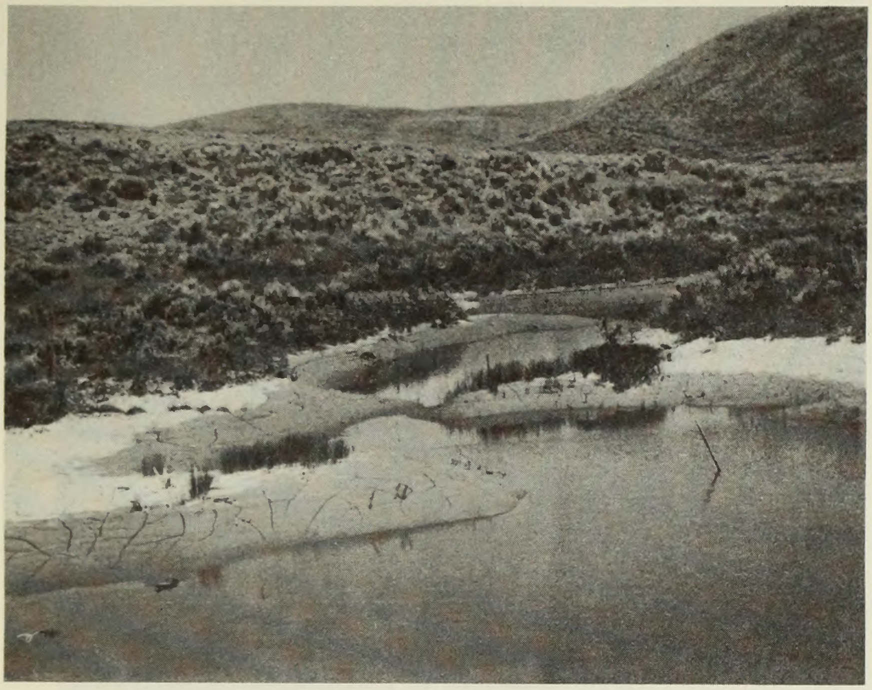

Figure 14. Deposition of silt behind a gully plug at Willow Creek.

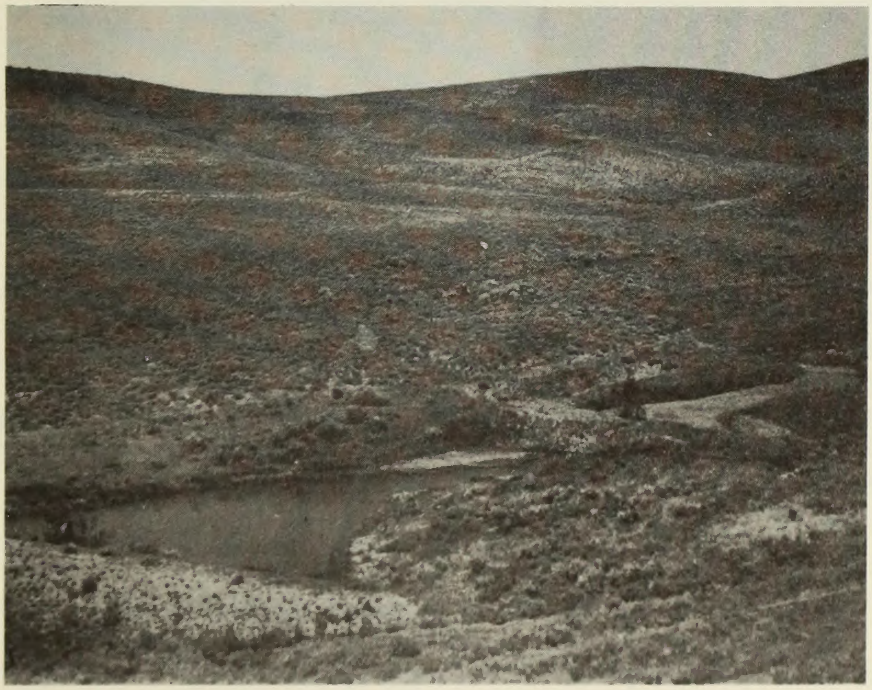

Figure 15. First reservoir (on right) and two gully plugs on Willow Creek. Runoff conditions in spring 1973 filled the first reservoir with sediment to a depth of about 4 feet. Very little sediment reached the second reservoir.

Figure 16. Closeup view of the first reservoir on Willow Creek, showing sediment deposition.

Direct evaluation of the effects of structures on the water table could not be made, because no measurements were taken before construction. However, water table measurements in relation to channel depth, proximity to the channel, and water control structures can give an indirect evaluation. Figure 17 presents the trend in water table depths from June 22 to October 17, 1967 under six different conditions.

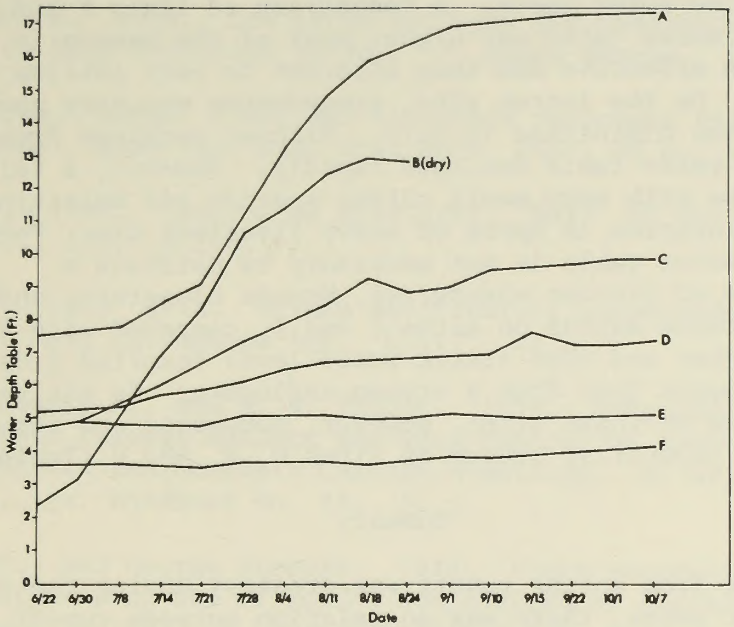

Figure 17. Trend in water table depth from June to October 1967. Line A represents a site with a 12 ft. channel without an effective dam. Line B represents a water table adjacent to a 1 ft. deep channel. Line C represents the water table on a site 72 feet from a live stream. Line D represents the water table on a site 15 feet from a live stream. Line E represents the water table on a site 46 feet from a reservoir. Line F represents the water table on a site 12 feet from a reservoir.

Line A represents the water table on a site with a 12 ft. channel and without an effective dam. Early in the summer, the water level is below the root zone of mesic herbaceous species. This site is a dryland environment, dominated by sedge and cheatgrass, with some big sagebrush and rabbitbrush.

Line B represents the water table adjacent to a one foot deep channel and no water control structure. The site has a fair condition stand of mesic meadow species. A comparison of lines A and B shows the effect of a deep channel on the water table. This comparison indicates that after a deep channel is cut, an effective dam is necessary to restore the water table to the level required by mesic meadow species.

Lines C and D represent sites where the water table is influenced by a stream, with the sites 72 and 15 feet from the channel, respectively. Lines E and F represent a water table influenced by a reservoir, with the sites 46 and 12 feet from the reservoir, respectively. A comparison of lines A and F shows that an effective dam can raise the water table. A comparison of lines F and B shows that the water table was higher most of the season in a 5 ft. channel with an effective dam than adjacent to very shallow channel without a dam. On the latter site, groundwater was very shallow until stream flow diminished in July. Without recharge from a reservoir, the water table declined rapidly. However, a fair condition meadow with many mesic climax species was maintained without brush invasion in spite of heavy livestock use. Perhaps a static high water table is not necessary to maintain a vegetative type of slender wheatgrass, Nevada bluegrass, and sedge. Water table depths on sites C and D, compared with E and F, show that a higher and more static water level resulted from a reservoir influence than from a stream influence. No native species remained on these sites, however, pubescent and intermediate wheatgrass had productive stands on sites D, E, and F (Table 3).

Summary

Peak water flow from spring runoff was greatest during the wettest year. In other years, there was no relation between runoff and precipitation. Willow Creek ran over its banks only during the wettest year and at only one location on the channel.

All drop-inlet pipes in the water control structure except one, in 2 years, had the capacity to handle stream flow. The two dams in the deepest channel did not hold water through the summer of any year. Two structures held water through the summer in some years, and one held water through the summer in all years. Some of the dams at Long Meadow, constructed without a core trench, failed. None of the structures at Willow Creek failed.

Only small amounts of sediment were collected behind the dams at Willow Creek. The greatest depths of sediment were found next to the structure. These deposits were attributed to movement of soil off the dam after construction, rather than to the sediments carried by the stream. The small amount of sediment deposition indicates that channel filling is a slow process except in years of catastrophic runoff events.

Evaluation of water table depths indicates that an effective dam can raise the water table. After a channel is cut, an effective dam is required to restore the water table to a level required by mesic, productive meadow species. An effective dam in a 5 ft. channel maintained a higher and more static water table than that found in a shallow channel without a dam. The height of water table maintained will influence the productivity of native and introduced vegetation.

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COMMON AND SCIENTIFIC NAMES OF PLANT SPECIES MENTIONED

Common Name	Scientific Name
Alta tall fescue	Festuca arundinacea
American plum	Prunus americana
Amur intermediate wheatgrass	Agropyron intermedium
Black chokecherry	Prunus virginiana var. melanocarpa
Big sagebrush	Artemisia tridentata
Cardinal olive	Elaeagnus umbellata
Cheatgrass	Bromus tectorum
Columbia needlegrass	Stipa columbiana
Common bladdersenna	Colutea arborescens
Common dandelion	Taraxacum officinale
Common lilac	Syringa vulgaris
Eski sainfoin	Onobrychis viciaefolia
European sagebrush	Artemisia abrotanum
Golden willow	Salix aurea
Ladak alfalfa	Medicago sativa
Luna pubescent wheatgrass	Agropyron trichophorum
Mat muhly	Muhlenbergia richardsonis
Meadow barley	Hordeum brachyantherum
Nevada bluegrass	Poa nevadensis
Pale agoseris	Agoseris glauca
Povertyweed	Iva axillaris
Rabbitbrush	Chrysothamnus spp.
Regar bromegrass	Bromus biebersteinii
Rocky Mountain iris	Iris missouriensis
Rush	Juncus spp.
Russian olive	Elaeagnus angustifolia
Sedge	Carex spp.
Siberian pea	Caragana arborescens
Primar slender wheatgrass	Agropyron trachycaulum
Squirreltail	Sitanion hystrix
Tatarian honeysuckle	Lonicera tatarica
Western yarrow	Achillea lanulosa

Table 1. Some climatic characteristics at the Willow Creek site and precipitation at the Long Meadow site.

Year	Precipitation (in.)		Growing season (Days above 32°F.)	Extreme air Temperature (°F.) 6/1 - 9/30		Mean monthly air temperature (°F.)								Evaporation from standard pan (in./wk.)
	Willow Creek	Long Meadow		Min.	Max.	June Min.	June Max.	July Min.	July Max.	August Min.	August Max.	September Min.	September Max.	
1964	12.9	--	70 1/	--	84	--	--	--	--	41.8	76.8	32.0	67.1	--
1965	8.1	15.6	92 1/	--	84	--	--	--	--	51.0	69.9	36.8	62.7	1.8
1966	14.9	20.4	72	24	93	40.6	73.6	47.1	82.5	50.9	83.1	--	--	2.4
1967	15.1	18.7	104 1/	38	90	--	--	48.5	77.4	48.5	79.9	42.5	70.8	2.6
1968	15.9	25.8	52	25	88	39.2	70.8	46.4	83.5	42.0	72.9	36.8	71.7	2.1
1969	33.2	19.9	87	26	89	36.3	61.5	47.2	76.0	44.6	82.1	41.4	72.1	1.6
1970	12.6	--	65	27	90	41.4	64.4	51.3	77.6	53.4	81.0	40.1	66.5	2.1
1971	23.4	--	--	--	--	--	--	--	--	--	--	--	--	--
1972	13.1	--	--	--	--	--	--	--	--	--	--	--	--	--

1/ Temperature data not collected until after June. Date of last day below 32° F. was taken from the average of the 1967 to 1970 data.

Table 2. Chemical composition (%) of seeded and meadow forbs.

	Seeded forbs 1/		Meadow forbs 2/		
	Narragansett alfalfa	Eski sainfoin	Succulent dandelion	Succulent yarrow	Mature dandelion
Ether extract	1.4	1.5	5.2	3.8	5.5
Crude fiber	26.6	23.7	14.6	19.5	18.4
Crude protein	18.8	19.1	19.1	23.9	15.7
Nitrogen-free extract	41.0	46.5	46.4	41.0	44.3
Ash	12.2	9.2	14.6	11.9	16.0

1/ Jensen, et al., 1968
2/ Oakleaf, 1971

Table 3. Yield (lbs./acre) of seeded and native species on upper and lower site at Willow Creek in 1970, 1971, and 1972. Seeding was made in fall 1968. The minimum (June) and maximum (August) water table depths (ft.) are also given.

Species	1970		1971		1972
	Upper	Lower	Upper	Lower	Lower
Luna pubescent wheatgrass	5,784	2,992	4,227	3,118	3,990
Amur intermediate wheatgrass	3,680	3,248	3,973	2,245	3,569
Regar bromegrass	1,424	1,784	408	1,720	1,561
Alta tall fescue	40	1,336	40	692	-- 1/
Primar slender wheatgrass	3,112		1,213		
Native sedge		1,879		2,286	2,000
Native slender wheatgrass		2,000		3,230	1,560
Range in water table depth from June to August	4.5-7.0	4.9-15.0	4.7-6.8	4.7-12.0	3.9-17.4

1/ Stand was considered a failure and was not harvested in 1972.

Table 4. Production (lbs./acre) of grass and grass-like species for 5 years after treatment in 1965 with 4 lbs./acre 2,4-D at Long Meadow.

Year	Production	
	Treated	Check
1966	486	212
1967	1,782	829
1968	776	288
1969	1,815	696
1970	2,296	944

Table 5. Production (lbs./acre) of grass, grass-like, and forb species on treated and check plots in 1970 at Long Meadow. Treatment (4 lbs./acre 2,4-D) was made in 1965.

Species	Production	
	Treated	Check
Slender wheatgrass	800	472
Nevada bluegrass	960	448
Meadow barley	352	16
Other grasses	160	0
Sedge	24	8
Iris	152	760
Common dandelion	32	40
Western yarrow	128	144
Other forbs	128	24
Total herbage	2,736	1,912
Grass and grass-like	2,296	944
Total forbs	440	968
Sage grouse food plants	160	184

Table 6. Forb production (lbs./acre) the year of 2,4-D application (1969) and for 2 years after application at Long Meadow.

2,4-D Rates (lbs./acre) and Application Date	Common Dandelion			Western Yarrow		
	1969	1970	1971	1969	1970	1971
Check	160	272	60	248	264	156
2 A		5	41		5	52
2 B		16	35		136	62
3 A		1	25		2	18
3 B		6	20		21	11
4 A		5	22		5	5
4 B		2	10		2	3

A date, 6/17 -- Dandelion phenology - second or third bloom, seeds from earlier flowers mostly disseminated.

-- Yarrow phenology - leaf to early flower bud.

B date, 7/8 -- Dandelion phenology - post-bloom, seed mostly disseminated.

-- Yarrow phenology - late bud to early flower.

Table 7. Yield (lbs./acre) of grass, grass-like, and forb species at Long Meadow in response to nitrogen fertilization. Nitrogen was reapplied at either 50, 100, or 200 lbs./acre to the same plot each year.

Species	1965 Rates of Nitrogen				1966 Rates of Nitrogen				1967 Rates of Nitrogen			
	Check	50	100	200	Check	50	100	200	Check	50	100	200
Nevada bluegrass	324	216	268	460	54	46	37	98	374	396	665	600
Slender wheatgrass	10	50	11	1	0	0	0	0	100	124	294	116
Columbia needlegrass	0	1	3	7	0	0	0	0	0	0	0	0
Mat muhly	5	68	12	4	0	0	0	0	0	118	0	107
Squirreltail	6	2	0	3	0	0	0	0	74	44	28	76
Sedge	18	58	1	53	530	563	763	734	0	0	44	39
Rush	0	2	0	0	13	15	36	8	27	0	0	0
Iris	182	251	233	96	258	239	220	117	294	492	438	190
Western yarrow	692	923	796	718	221	101	265	122	935	583	945	528
Dandelion	0	0	0	0	0	0	0	0	604	650	796	684
Other forbs	0	0	0	0	0	0	0	0	27	0	0	107

Table 8. Yield (lbs./acre) of grass, grass-like, and forb species at Willow Creek in response to nitrogen fertilization. Nitrogen was reapplied at either 50, 100, or 200 lbs./acre to the same plot each year.

Species	1964 Rates of Nitrogen Check	50	100	200	1965 Rates of Nitrogen Check	50	100	200
Nevada bluegrass	255	237	127	257	70	256	255	430
Slender wheatgrass	488	1,084	1,264	1,001	112	248	195	290
Columbia needlegrass	162	0	0	0	0	0	8	0
Mat muhly	227	179	262	359	107	66	63	0
Sedge	468	744	827	850	105	144	172	123
Rush	10	62	0	0	94	41	18	54
Iris	498	919	762	1,039	104	248	195	101
Western yarrow	31	65	108	100	82	113	226	273
Dandelion	9	15	21	26	43	86	50	28
	1966				1967			
Nevada bluegrass	42	34	28	302	653	1,087	1,705	1,559
Slender wheatgrass	133	206	390	409	504	1,615	1,362	2,494
Columbia needlegrass	0	9	4	0	0	0	0	0
Mat muhly	135	67	86	80	201	253	317	305
Sedge	235	456	635	455	366	949	549	894
Rush	165	213	177	58	173	66	0	0
Iris	44	126	60	0	158	208	18	8
Western yarrow	40	0	30	0	282	227	20	88
Dandelion	5	0	22	0	0	46	0	0

Table 9. Peak flow of water in the Willow Creek channel during spring runoff.

Year	Peak flow-depth (in.) Site 1	2	3	4
1964	8.0	6.1	8.2	16.0
1965	8.0	9.8	7.5	8.0
1966	1.5	6.0	6.5	6.0
1967	9.0	8.0	11.0	8.0
1968	1.5	3.5	4.5	3.5
1969	5.0	11.0	19.5	26.0
1970	7.0	8.5	8.0	7.0
1971	9.0	9.8	9.5	8.5

Site 1. Channel is located above the meadow in the sagebrush type, is about 1 foot deep, and is usually dry by late spring. Water source is the upstream watershed.

Site 2. Channel is in the upper meadow and is about 5 feet deep, and water runs most of the summer. Water source is the upstream watershed and a spring immediately upstream.

Site 3. Channel is in the lower meadow and is about 1 foot deep. Water runs all year. Water source is the upstream watersheds on two streams, numerous springs, and a storage dam immediately upstream.

Site 4. Channel is in the lower meadow and is about 10 feet deep. Water runs only until July in most years. Water source is the upstream watershed on two streams, numerous springs, and a storage dam immediately upstream.

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